

Supplementary Materials: Tailoring Piezoresistive Performance in 3D-Printed Nanocomposite Sensors Through Cellular Geometries

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1. Slicing of CAD

Figure S1 shows the layout of the print bed in the 3D printer slicer software.

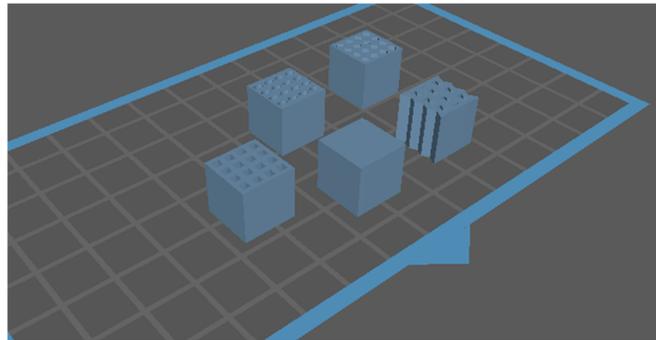


Figure S1. Print bed layout in slicer.

2. Boundary Condition

The material properties of the sensors were defined using the Yeoh hyperelastic material model, with uniaxial test data obtained from experimental compression tests. The relationship between resistivity and pressure, derived from electromechanical testing, was defined as the electrical property through the USDFLD subroutine. The compression plates were modeled as steel, with a Young's modulus of 210 GPa and a Poisson's ratio of 0.3. Small sliding with a friction coefficient of 0.3 was set for the contact area between the compression plates and the sensor to ensure that the simulations accurately capture the contact mechanics at the interface.

The bottom plates were defined as encastre to avoid any rotational and translational slippage, and the top plate was constrained to move only along the Y-axis to apply uniform compression. To ensure consistent and measurable potential differences across the sample during compression, zero voltage was applied to the bottom surface of the sensor, and a constant current (0.1A) was applied to the top surface of the sensor to mimic operational conditions for the piezoresistive sensors. These constraints helped isolate the deformation behavior of the flexible sensors, ensuring that any observed effects were due to the topology rather than external variables. As the electromechanical testing demonstrated the high sensitivity of sensors in response to the pressure, the uniform pressure (30 kPa) was selected to simulate practical conditions. The FEA setup for reference is shown in Figure S2.

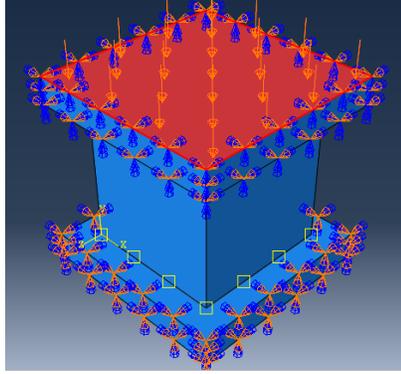


Figure S2. Reference cubic sample under uniform pressure.

3. Parametric Study

The finite element analysis (FEA) was performed on each elliptical (Figure S3) and diamond structure (Figure S4) using material and electrical properties obtained from the experimental data of the reference sample.

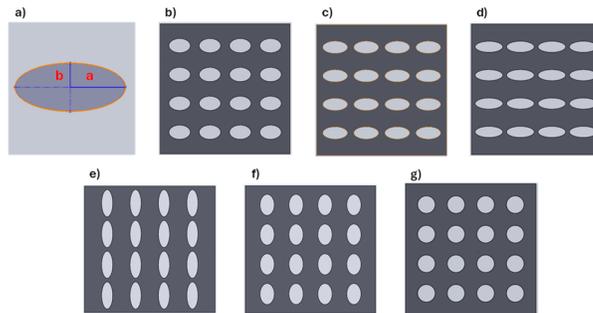


Figure S3. a) Ellipse parameters. b) ES01, c) ES02, d) ES03, e) ES04, f) ES05, g) ES06.

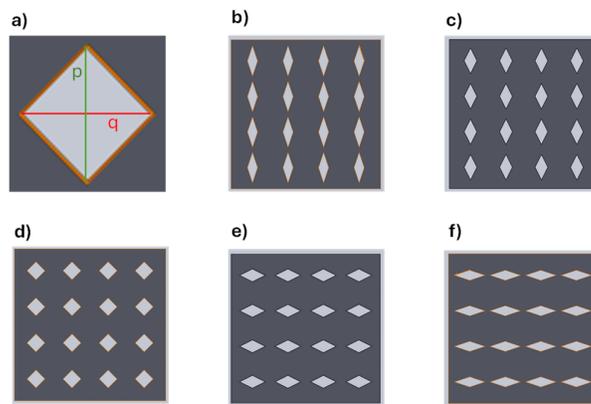


Figure S4. a) Diamond parameters. b) DS01, c) DS02, d) DS03, e) DS04, f) DS05.

This method ensured consistent material behavior, allowing a thorough understanding of the impact of different topological configurations on piezoresistive sensitivity. The sensitivity of each structure was determined by measuring the change in electrical resistance when mechanical stress was applied, providing a direct measure of piezoresistive performance. Figure S5 demonstrates the localized stress concentration for different configurations of ellipse structures along compressive load direction.

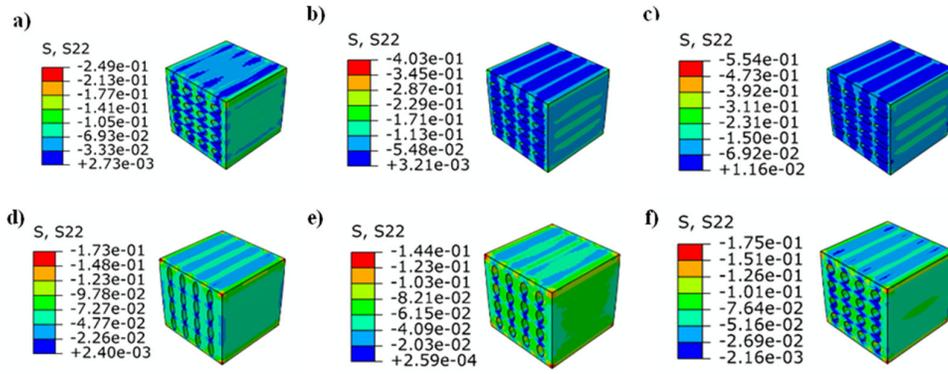


Figure S5. a) ES01, b) ES02, c) ES03, d) ES04, e) ES05, f) ES06.

The results from diamond structures (Figure S6) reaffirm that optimizing the structural design to concentrate stress in specific regions enhances piezoresistive sensitivity which is a key factor for developing flexible sensors with improved performance.

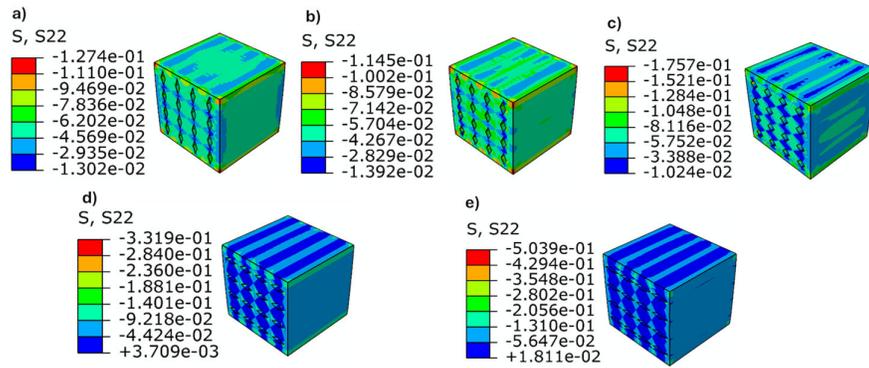


Figure S6. a) DS01, b) DS02, c) DS03, d) DS04, e) DS05.